

GEOL 321L Structural Geology and Tectonics: Spring 2021

Geol 321L Structural Geology and Tectonics introduces basic concepts in both tectonics and structural geology, including plate tectonics, deformational structures at scales from the hand-specimen to plate boundaries, and how these structures relate to plate tectonic settings. The emphasis will be on the description and interpretation of structures seen in the field, and the course includes an introduction to the techniques of geological mapping in an area of deformed rocks, and the interpretation of geological maps and cross-sections. Lab exercises will involve some calculations and graphical exercises, but a basic math preparation is sufficient to follow the course. An introductory geology course, and a basic knowledge of minerals and rocks, are recommended preparation.

Primary learning objectives include analysis of plate motions, methods of measurement and analysis of structural data, mechanical analysis of deformational structures, strain analysis, restoration and balancing of cross sections, interpretation of geological maps, and field methods of structural analysis and construction of geological maps.

Instructors: Professor John Platt, ZHS313, jplatt@usc.edu. Office hour: Thursday 12-1.
TA: Naomi Rodgers, ZHS 129, nrogers@usc.edu

Assigned text: Davis, G.H., Reynolds, S.J., and Kluth. *Structural Geology of Rocks and Regions*. 3rd Edition. Wiley. ISBN: 978-0-471-15231-6.

Additional recommended text: Moores, E.M. & Twiss, R.J., *Tectonics*. Freeman 1995. Reissued 2014 by Waveland Press. ISBN-13: 978-1478621997

Lectures are on Tuesdays and Thursdays, 2 – 3.20 pm, and will initially be on-line. If the University opens for in-person teaching, lectures will be in ZHS 200. Pdf files of lecture slides, plus associated course notes, will be posted on Blackboard.

Labs are scheduled on Friday, 9-10.50 am, and will be held in person in ZHS B54 under current USC plans, but this may change. Lab materials will be posted on-line as appropriate, and labs will be graded weekly.

Field trips. If domestic travel is allowed by the University, there will be two one-day field trips and two weekend trips, including a mapping trip in the Inyo Mountains. For weekend trips we will leave early on the Friday, and return late Sunday. We will camp and self cater; transportation will be provided and all other costs covered by the Department. The day trips will be scheduled on Fridays, in place of lecture and lab, but which means you will need to reschedule any other commitments you have on those days. A provisional schedule for these trips follows:

Field exercise 1: Southern California tectonics (day trip, Feb 12)

Field exercise 2: Death Valley (weekend trip March 5-7)

Field exercise 3: Field methods in structural geology (day trip, March 26)

Field exercise 4: Mapping in the Inyo Mtns (weekend trip, April 16-18).

Field note-books and exercises completed in the field will be assessed and graded.

Grading. Assessment is based on lab assignments (50%), field trip reports (25%), and a final examination (25%). Weightings may be adjusted if the schedule has to be modified because of the pandemic.

Lecture schedule:

Jan 19, 21: Plate tectonics: fundamentals

Reading: Davis & Reynolds chapter 10.

Lecture 1: The Earth as a mechanical system.

- Heat flow and the global energy budget
- Conduction and convection
- Compositional boundaries within the Earth
- Lithosphere and asthenosphere. Thermal and mechanical boundary layers.
- Decompression melting and the origin of the oceanic crust
- Isostasy, gravity and topography

Lecture 2: Continental drift and plate tectonics

- Geological evidence for continental drift
- Apparent polar wander paths
- Distribution of seismicity
- Sea-floor magnetic anomalies
- Plate tectonics as a geometrical theory

Lab exercise 1: Introduction to geological maps 1

Jan 26, 28: Plate kinematics and plate boundaries

Reading: Moores & Twiss, sections 5.1 - 5.5.

Lecture 3: Geometrical theory of plate tectonics

- Euler's theorem
- Relative velocities and poles of rotation
- Kinematic and geometrical characteristics of plate boundaries
- Triple junctions

Lecture 4: Divergent plate boundaries and transform faults

- Topographic and structural expression of mid-ocean ridges
- Subsidence history of oceanic lithosphere
- Magmatism at mid-ocean ridges
- Petrology and structure of oceanic crust as revealed in ophiolite sequences
- Kinematics of transform faults
- Seismicity and topographic expression of transform faults

Lab exercise 2: Plate kinematics

Feb 2, 4: Plate boundaries continued

Reading: Moores & Twiss, section 5.6 and 7.1 – 7.4, Davis & Reynolds, p. 340-357.

Lecture 5: Convergent plate boundaries

- Benioff seismic zones
- Surface structure: Accretionary wedge – forearc basin – magmatic arc – back-arc
- Introceanic and continental arcs
- Continental collision zones

Lecture 6: Continental rift zones and the evolution of passive continental margins

- Structure of continental rifts. East African Rift as an example
- Initiation of continental breakup. Red Sea as an example
- Evolution of passive continental margins: Atlantic margin of eastern US as an example.

Lab exercise 3: Introduction to geological maps 2

Feb 9, 11: Faults

Reading: Davis & Reynolds, p. 269-296

Lecture 7: Fault geometry

- Description of deformation in terms of geometry, kinematics, and dynamics.
- Geometrical description of faults. Slip and stratigraphic separation on faults.
- Methods for determining the slip vector on a fault.

Field exercise 1: Southern California tectonics (day trip, Friday Feb 12).

Feb 16, 18: Fault rocks; fold geometry

Lecture 8: Fault rocks and small-scale structures in fault zones.

- Fault rocks: fault breccia, cataclasite, mylonite, pseudotachylite
- Slickensides and slickenlines
- Gouge fabrics, Riedel shears
- Wear grooves, fibre lineations, solution grooves
- Sense of shear indicators in fault zones.

Lecture 9: Geometrical description of folds

Reading, Davis & Reynolds, ch 7.

- Fold hinge, axis, axial surface, fold crest
- Inclined folds and plunging folds
- Fold asymmetry, enveloping surface of a fold train
- Fold style: parallel, concentric, similar, kink geometries.

Lab exercise 4: Introduction to the equal-area projection

Feb 23, 25: Folds and fabrics; mechanics

Lecture 10: Folds and rock fabrics

- Axial plane cleavage in folds.
- Linear fabric elements in folds.
- Use of folds, cleavages and lineations in structural analysis

Lecture 11: Introduction to Structural Mechanics

Reading: Davis & Reynolds, p. 98-122; 304-310.

- Force and stress
- Stress on a surface: tractions and the stress vector
- Stress field in 3-D; Principal stresses
- Hydrostatic and deviatoric stress
- Mohr equations and the Mohr construction for stress

Lab exercise 5: Geometrical analysis of folds

March 2, 4: Fracture mechanics

Lecture 12: Fracture mechanics

- The Coulomb fracture criterion.
- Use of the Mohr construction to represent fracture mechanics
- Failure envelope
- Effect of fluid pressure on fracture

Lecture 13: Introduction to Death Valley

Field exercise 2: Death Valley (weekend trip March 5-7)

March 9, 11: Strain

Reading: Davis & Reynolds, p. 38-74

Lecture 14: Ductile deformation and strain

- Displacement gradients, rotation, and strain.
- Elongation, stretch, shear strain, volumetric strain
- Incremental strain and strain-rate

Lecture 15: Strain analysis

- Strain analysis using spherical objects
- Center-to-center method
- R_f/ϕ method
- Mohr construction for strain
- Strain analysis using deformed fossils

Lab exercise 6: The Mohr construction for stress and its use in fracture mechanics

March 16, 18 Rock Rheology and fabrics

Reading, Davis & Reynolds, p. 143-149

Lecture 16: Rheology

- Rheology
- Elastic, viscous and plastic deformation
- Rheological analogues
- Deformational mechanisms in rocks

Lecture 17: Ductile deformational fabrics

Reading, Davis & Reynolds, ch 8.

- Planar deformational fabrics: cleavage, schistosity, gneissic foliation, mylonitic foliation, crenulation cleavage.
- Linear deformational fabrics: intersection lineation, stretching lineation, crenulation lineation.

Lab exercise 7: Strain analysis

March 23, 25: Ductile Shear zones

Reading: Davis & Reynolds, p. 493-523, 404-413

Lecture 18: Ductile shear zones

- Boundary conditions limiting nature of flow in ductile shear zones
- Geometry of simple shear
- Foliation geometry in ductile shear zones
- Mylonites
- Sense of shear criteria in mylonites

Field exercise 3: Field methods in structural geology (day trip, Friday March 26)

March 30, April 1: Mechanics of folding

Lecture 19: Mechanics of folding 1

- Fold style in terms of the geometry of the folded layer
- Mechanical theory of buckle folding in single layers.

Lecture 20: Mechanics of folding 2

- Folding in multilayers; flexural slip folds
- Kinks.
- Similar folds and flow folds

Lab exercise 8: Field trip follow-up exercise

April 6, 8: Polyphase deformation, strike-slip tectonics

Lecture 21: Analysis of polyphase deformation

- Superposed folds
- Interference structures
- Folded foliations and superposed foliations
- Folded lineations

Tectonics

Lecture 22: Tectonic styles in zones of strike-slip faulting

- Patterns of folds and faults in strike-slip fault zones
- Flower structures
- Releasing and restraining bends
- Pull-apart basins
- Vertical-axis rotations in in strike-slip fault zones
- Deep structure of strike-slip fault zones

Lab exercise 9: Structures and fabrics in rocks

April 13, 15: Extensional tectonics

Lecture 23: Tectonic styles in zones of normal faulting

- Conjugate sets of normal faults
- Horst and graben structure
- Detachment faults
- Rotation of normal faults above listric faults and detachments
- Rolling hinge model for detachment faults

Lecture 24: Introduction to the field mapping exercise

Field exercise 4: Mapping in the Inyo Mtns (weekend trip, April 16-18).

April 20, 22: Thrust tectonics

Lecture 25: Tectonic styles in zones of thrust faulting

- Thin-skinned and thick-skinned thrust belts
- Ramp and flat structures
- Ramp anticlines and footwall synclines
- Fault propagation folds
- Frontal imbricate fan
- Duplex structure
- Culminations
- Backthrusts and pop-up structures

Lecture 26: Construction and restoration of balanced sections

Lab exercise 10: Field trip follow-up

April 27, 29: Review

Lecture 27: Review session

Lecture 28: Review session

Lab exercise 11: Construction and restoration of balanced sections

FINAL EXAMINATION: Thurs May 6, 2-4 pm.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, “Behavior Violating University Standards” policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press “0” after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) - (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity | Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776

dsp.usc.edu

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710

campussupport.usc.edu

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101

diversity.usc.edu

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

dps.usc.edu, emergency.usc.edu

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call

dps.usc.edu

Non-emergency assistance or information.